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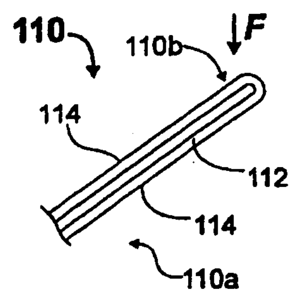
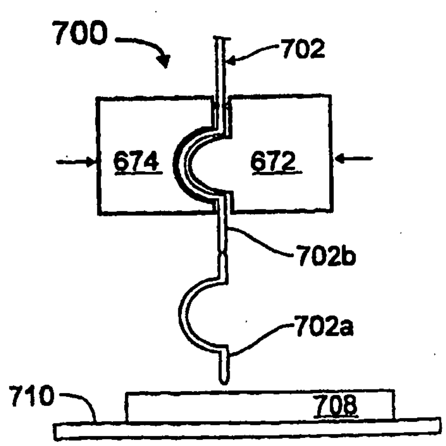
(54) Title: SPRING ELEMENT ELECTRICAL CONTACT AND METHODS

(57) Abstract

Spring elements (540) for use as electrical contacts are fabricated by shaping a relatively soft core (112, 122) and overcoating the shaped core (702) with a relatively hard material (114, 124). Additional overcoat layers may be applied to enhance the electrical characteristics of the resulting spring element (540). The spring elements (540) are fabricated from an elongate element (602) which is shaped to exhibit a plurality of spring element cores linked end-to-end, which are then overcoated. The resulting spring elements (540) may then be attached to electronic components (708) by automated machinery (620). An external shaping tool is disclosed, which is particularly useful for shaping a plurality of linked and separable spring elements (540) which are inherently springy (i.e., formed of a relatively hard material).





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"SPRING ELEMENT ELECTRICAL CONTACT AND METHODS"

TECHNICAL FIELD OF THE INVENTION

The invention relates to making pressure connections between electronic components and, more particularly, to techniques for fabricating spring elements (socket elements) for connectors.

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is a continuation-in-part of commonly-owned, copending U.S. Patent Application No. **08/452,255** (hereinafter "PARENT CASE") filed 26 May 95 and its counterpart PCT patent application number PCT/US95/14909 filed 13 NOV 95, both of which are continuations-in-part of commonly-owned, copending U.S. Patent Application No. **08/340,144** filed 15 Nov 94 and its counterpart PCT patent application number PCT/US94/13373 filed 16 Nov 94 (published 26 May 95 as WO 95/14314), both of which are continuations-in-part of commonly-owned, copending U.S. Patent Application No. 08/152,812 filed 16 Nov 93 (now **USP 5,476,211**, 19 Dec 95), all of which are incorporated by reference herein.

This patent application is also a continuation-in-part of the following commonly-owned, copending U.S. Patent Application Nos.:

08/526,246 filed 21 SEP 95 (PCT/US95/14843, 13 NOV 95);
08/533,584 filed 18 OCT 95 (PCT/US95/14842, 13 NOV 95);
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60/012,040 filed 22 FEB 96;
60/012,878 filed 05 MAR 96;
60/013,247 filed 11 MAR 96; and
60/005,189 filed 17 MAY 96

all of which are continuations-in-part of the aforementioned PARENT CASE, and all of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION

Copending, commonly-owned U.S. Patent Application No. 04/452,255 filed 26 May 1995 (and its counterpart PCT/US95/14909), hereinafter "PARENT CASE", incorporated by reference herein, describes fabricating spring contacts (resilient contact structures, composite interconnection elements) on electronic components such as semiconductor (integrated circuit) devices which may be resident (unsingulated) on a semiconductor wafer. The same spring elements may be used to effect "temporary" pressure connections to the semiconductor dies, such as for performing burn-in and testing, and to mount the dies to other electronic components such as a printed circuit board (PCB). Other embodiments include mounting spring elements to substrates for use as interposers, using the spring elements as probes, fabricating spring elements on sacrificial substrates for later attachment to electronic components, fabricating contact tips for attachment to the spring elements, fabricating spring elements having controlled impedance, etc..

To effect reliable pressure connections to an electronic component, one must be concerned with several parameters including, but not limited to (nor including each and every one of): alignment, probe force, overdrive, contact force, balanced contact force, scrub, contact resistance, and planarization.

Generally, interconnections between electronic components can be classified into the two broad categories of "relatively permanent" and "readily demountable".

An example of a "relatively permanent" connection is a solder joint. Once two components are soldered to one another, a process of unsoldering must be used to separate the components. A wire bond is another example of a "relatively

permanent" connection.

An example of a "readily demountable" connection is rigid pins of one electronic component (e.g., a semiconductor package) being received by resilient socket elements (spring elements) of another electronic component. The socket elements exert a contact force (pressure) on the pins in an amount sufficient to ensure a reliable electrical connection therebetween.

Interconnection elements intended to make pressure contact with terminals of an electronic component are referred to herein as "springs" or "spring elements" or "spring contacts" or "socket elements". Generally, a certain minimum contact force is desired to effect reliable pressure contact to electronic components (e.g., to terminals on electronic components). For example, a contact (load) force of approximately 15 grams (including as little as 2 grams or less and as much as 150 grams or more, per contact) may be desired to ensure that a reliable electrical connection is made to a mating element (e.g., a pin of a semiconductor package) which may be contaminated with films on its surface, or which has corrosion or oxidation products on its surface. The minimum contact force required of each spring element demands either that the yield strength of the spring material or that the size of the spring element are increased. As a general proposition, the higher the yield strength of a material, the more difficult it will be to work with (e.g., punch, bend, etc.). And the desire to make spring elements smaller essentially rules out making them larger in cross-section.

Spring elements are commonly fabricated from a relatively hard (high yield strength) material, requiring commensurately strong tooling, and may be fabricated in a linked but separable manner to facilitate automated handling thereof, such as insertion into the body of a socket. This hard material, such

as phosphor bronze and beryllium copper may be plated, such as with gold, to provide enhanced electrical contact.

Attention is directed to U.S. Patent No. 5,045,975 issued 03 Sep 91, entitled THREE-DIMENSIONALLY INTERCONNECTED MODULE ASSEMBLY, which discloses ball bonding a plurality of gold wires (leads) onto and substantially perpendicular to an integrated circuit die, and inserting the gold leads into plated through holes of printed circuit boards to effect an electrical and mechanical connection therebetween. The technique is also useful for interconnecting sandwiched assemblies of circuit boards. This patent illustrates the feasibility of adding a notching mechanism to a wirebonder (ball bonder), and also illustrates the technique of electrostatic flame off (EFO).

BRIEF DESCRIPTION (SUMMARY) OF THE INVENTION

It is an object of the present invention to provide an improved technique for fabricating spring elements for use as electrical contact structures (spring contacts).

According to the invention, a plurality of spring contacts are fabricated from an elongate element, and are linked end-to-end.

According to an aspect of the invention, the linked spring contacts are formed by wirebonding apparatus incorporating an external instrumentality (shaping tool) for imparting spring shapes to the elongate element, and for partially severing (nicking) the elongate element between successive linked spring contacts.

Severing an elongate element feeding from a capillary of a wirebonder is readily done with a spark (electrical discharge) from an electronic flame-off electrode (EFO). It is within the scope of this invention that an elongate element having a series of shaped elements linked end-to-end, separated by a nick, can be severed by a spark. According to an aspect of the invention, in such a case, the nick being a region of reduced cross-section, spark-severing will be more precisely controlled.

In an embodiment of the invention, an elongate element of a material (such as gold) that is relatively soft and readily shaped is fashioned into a plurality of linked "cores". The elongate element is then overcoated with a relatively hard material (such as nickel) to impart the desired spring characteristics (resiliency) to the resulting linked spring elements ("composite interconnection elements").

The use of the term "composite", throughout the description

set forth herein, is consistent with a 'generic' meaning of the term (e.g., formed of two or more elements), and is not to be confused with any usage of the term "composite" in other fields of endeavor, for example, as it may be applied to materials such as glass, carbon or other fibers supported in a matrix of resin or the like.

A "composite" spring contact element is different than a "monolithic" spring contact element. The composite spring contact elements of the invention derive their resilient (mechanical) characteristics from an overcoat (e.g., plating) which includes at least one layer of a high yield strength material (e.g., nickel). Monolithic spring contact elements derive their resilient (mechanical) characteristics from their core material, which may be plated (e.g., with gold) to enhance electrical connectivity.

As used herein, the term "spring shape" refers to virtually any shape of an elongate element which will exhibit elastic (restorative) movement of a portion of the elongate element with respect to a force applied to the elongate element. This includes elongate elements shaped to have one or more bends, as well as substantially straight elongate elements.

In an embodiment of the invention, the core is a "soft" material having a relatively low yield strength, and is overcoated with at least one layer of a "hard" material having a relatively high yield strength. For example, a soft material such as an elongate gold element is shaped to have a plurality of cores having spring shapes, is overcoated (e.g., by electrochemical plating) with a hard material such nickel and its alloys.

Vis-a-vis overcoating the core, single and multi-layer overcoatings, "rough" overcoatings having microprotrusions (see

also Figures 5C and 5D of the PARENT CASE), and overcoatings extending the entire length of or only a portion of the length of the core, are described.

Generally, throughout the description set forth herein, the term "plating" is used as exemplary of a number of techniques for overcoating the core. It is within the scope of this invention that the core can be overcoated by any suitable technique including, but not limited to: various processes involving deposition of materials out of aqueous solutions; electrolytic plating; electroless plating; "barrel" plating; chemical vapor deposition (CVD); physical vapor deposition (PVD); processes causing the deposition of materials through induced disintegration of liquid or solid precursors; and the like, all of these techniques for depositing materials being generally well known.

Generally, for overcoating the core with a metallic material such as nickel, electrochemical processes are preferred, especially electrolytic plating.

Preferably, the elongate core element is in the form of a conductive metallic ribbon.

Representative materials, both for the elongate core element and for the overcoatings, are disclosed.

In the main hereinafter, techniques involving beginning with a relatively soft (low yield strength) core element, which is generally of very small dimension (e.g., 3.0 mil or less) are described. Soft materials, such as gold, generally lack sufficient resiliency to function as springs. (Such soft, metallic materials exhibit primarily plastic, rather than elastic deformation.) Other soft materials which may possess appropriate resiliency are often electrically non-conductive,

as in the case of most elastomeric materials. In either case, desired structural and electrical characteristics can be imparted to the resulting spring element by the overcoating applied over the core element. The resulting spring element can be made very small, yet can exhibit appropriate contact forces. Moreover, a plurality of such spring elements can be arranged at a fine pitch (e.g., 10 mils), even though they have a length (e.g., 100 mils) which is much greater than the distance to a neighboring spring element (the distance between neighboring spring elements being termed "pitch").

The spring elements of the present invention exhibit superior electrical characteristics, including electrical conductivity, solderability (optional) and low contact resistance. In many cases, deflection of the spring element in response to applied contact forces results in a "wiping" contact, which helps ensure that a reliable contact is made.

It should clearly be understood that the composite interconnection element (spring contact element) of the present invention differs dramatically from spring elements of the prior art which may have been coated to enhance their electrical conductivity characteristics or to enhance their resistance to corrosion. The overcoating of the present invention is specifically intended to impart desired resilient characteristics to the resulting spring element. In this manner, stresses (contact forces) may be directed to portions of the spring elements which are specifically intended to absorb the stresses.

It should also be appreciated that the present invention provides essentially a new technique for making spring contacts. Generally, the operative structure of the resulting spring is a product of plating, rather than of bending and shaping. This opens the door to using a wide variety of materials to establish

the spring shape. The overcoating functions as a "superstructure" over the "falsework" of the core, both of which terms have their origins in the field of civil engineering.

The present invention is also useful for forming a plurality of linked spring contacts from a material which does not need to be overcoated with a harder (higher yield strength) material in order to function as a spring contact. Such spring contacts may optionally be overcoated to enhance their electrical characteristics (e.g., solderability, contact resistance, etc.) and/or to more securely anchor the spring contact to a substrate (including a terminal of an electronic component), and are termed "monolithic" interconnection elements.

Other objects, features and advantages of the invention will become apparent in light of the following description thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will be made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Although the invention will be described in the context of these preferred embodiments, it should be understood that it is not intended to limit the spirit and scope of the invention to these particular embodiments.

In the side views presented herein, often portions of the side view are presented in cross-section, for illustrative clarity. For example, in many of the views, the wire stem is shown full, as a bold line, while the overcoat is shown in true cross-section (often without crosshatching).

In the figures presented herein, the size of certain elements are often exaggerated (not to scale, vis-a-vis other elements in the figure), to provide illustrative clarity.

Figure 1A is a cross-sectional view of a longitudinal portion, including one end, of an interconnection element, according to an embodiment of the invention.

Figure 1B is a cross-sectional view of a longitudinal portion, including one end, of an interconnection element, according to another embodiment of the invention.

Figure 1C is a cross-sectional view of a longitudinal portion, including one end of an interconnection element, according to another embodiment of the invention.

Figure 1D is a cross-sectional view of a longitudinal portion, including one end of an interconnection element, according to another embodiment of the invention.

Figure 1E is a cross-sectional view of a longitudinal portion, including one end of an interconnection element, according to another embodiment of the invention.

Figure 2A is a cross-sectional view of an interconnection element mounted to a terminal of an electronic component and having a multi-layered shell, according to the invention.

Figure 2B is a cross-sectional view of an interconnection element having a multi-layered shell, wherein an intermediate layer is of a dielectric material, according to the invention.

Figure 3 is a cross-sectional view of a socket incorporating socket elements, according to an embodiment of the present invention.

Figure 4A is a plan view of a technique for forming socket elements, according to an alternate embodiment of the present invention.

Figure 4B is a perspective view of a further step in the technique of **Figure 4A**, according to the present invention.

Figure 4C is a perspective view of a further step in the technique of **Figure 4B**, according to the present invention.

Figure 4D is a cross-sectional view of a socket element formed according to the technique of **Figures 4A-4C**, according to the present invention.

Figure 5A is a cross-sectional view of a technique for forming linked contact elements, according to the prior art.

Figure 5B is a cross-sectional view of a technique for forming linked contact elements, according to an embodiment of

the invention.

Figure 5C is a cross-sectional view of a technique for forming linked contact elements, according to another embodiment of the invention.

Figure 6 is a perspective view of wirebonding apparatus, illustrating an embodiment of an external shaping tool, according to the invention.

Figures 6A is a side view of a method of shaping an elongate element (e.g., wire) with the shaping tool of **Figure 6**, including a feature of the shaping tool for nicking or severing the elongate element, according to the invention.

Figure 6B is a side view of an elongate element that has been nicked to define a series of shaped (illustrated as straight, for illustrative clarity, compare **Figure 7**) elongate elements which are linked end-to-end, according to the invention.

Figure 7 is a side view of a technique for inserting a plurality of shaped elongate elements into a substrate, according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

This patent application is directed to techniques of fabricating spring contact elements, such as for making socket elements for effecting connections to packaged semiconductor devices. Preferably, the resilient contact structures are implemented as "composite interconnection elements", such as have been described in the disclosure of commonly-owned, copending U.S. Patent Application No. **08/452,255**, filed 5/26/95 ("PARENT CASE"), incorporated by reference herein. This patent application summarizes several of the techniques disclosed in the PARENT CASE, and also summarizes certain of the techniques disclosed in commonly-owned, copending U.S. Patent Application No. **08/526,246**, incorporated by reference herein.

An important aspect of the preferred technique for practicing the present invention is that a "composite" interconnection element can be formed by starting with a core element, then overcoating the core element with an appropriate material to establish the mechanical properties of the resulting composite interconnection element. In this manner, a spring contact (element) can be fabricated, starting with a core of a soft material which is readily shaped into a springable shape. In light of prior art techniques of forming spring elements from hard materials, is not readily apparent, and is arguably counter-intuitive, that soft materials can form the basis of spring elements.

Figures 1A, 1B, 1C and 1D illustrate, in a general manner, various shapes for composite interconnection elements, such as have been described in commonly-owned, copending U.S. Patent Application No. **08/526,246**. In the main hereinafter, composite interconnection elements that have a soft (relatively low yield strength) core, overcoated by hard (relatively high yield strength) materials are described.

In **Figure 1A**, an electrical interconnection element 110 includes a core 112 of a "soft" material (e.g., a material having a yield strength of less than 40,000 psi), and a shell (overcoat) 114 of a "hard" material (e.g., a material having a yield strength of greater than 80,000 psi). The core 112 is an elongate element shaped (configured) as a substantially straight cantilever beam, and may be a wire having a diameter of 0.0005-0.0030 inches (0.001 inch = 1 mil ≈ 25 microns (μm)). The shell 114 is applied over the already-shaped core 112 by any suitable process, such as by a suitable plating process (e.g., by electrochemical plating).

Figure 1A illustrates what is perhaps the simplest of spring shapes for an interconnection element of the present invention - namely, a straight cantilever beam oriented at an angle to a force "*F*" applied at its tip 110b. When such a force is applied by a terminal of an electronic component to which the interconnection element is making a pressure contact, the downward (as viewed) deflection of the tip will evidently result in the tip moving across the terminal, in a "wiping" motion. Such a wiping contact ensures a reliable contact being made between the interconnection element and the contacted terminal of the electronic component.

By virtue of its "hardness", and by controlling its thickness (0.00025-0.00500 inches), the shell 114 imparts a desired resiliency to the overall interconnection element 110. In this manner, a resilient interconnection between electronic components (not shown) can be effected between the two ends 110a and 110b of the interconnection element 110. (In **Figure 1A**, the reference numeral 110a indicates an end portion of the interconnection element 110, and the actual end opposite the end 110b is not shown.) In contacting a terminal of an electronic component, the interconnection element 110 would be subjected

to a contact force (pressure), as indicated by the arrow labelled "*F*".

It is generally preferred that the thickness of the overcoat (whether a single layer or a multi-layer overcoat) be thicker than the diameter of the wire being overcoated. Given the fact that the overall thickness of the resulting contact structure is the sum of the thickness of the core plus twice the thickness of the overcoat, an overcoat having the same thickness as the core (e.g., 1 mil) will manifest itself, in aggregate, as having twice the thickness of the core.

The interconnection element (e.g., 110) will deflect in response to an applied contact force, said deflection (resiliency) being determined in part by the overall shape of the interconnection element, in part by the dominant (greater) yield strength of the overcoating material (versus that of the core), and in part by the thickness of the overcoating material.

As used herein, the terms "cantilever" and "cantilever beam" are used to indicate that an elongate structure (e.g., the overcoated core 112) is mounted (fixed) at one end, and the other end is free to move, typically in response to a force acting generally transverse to the longitudinal axis of the elongate element. No other specific or limiting meaning is intended to be conveyed or connoted by the use of these terms.

In **Figure 1B**, an electrical interconnection element 120 similarly includes a soft core 122 (compare 112) and a hard shell 124 (compare 114). In this example, the core 122 is shaped to have two bends, and thus may be considered to be S-shaped. As in the example of **Figure 1A**, in this manner, a resilient interconnection between electronic components (not shown) can be effected between the two ends 120a and 120b of the interconnection element 120. (In **Figure 1B**, reference numeral

120a indicates an end portion of the interconnection element 120, and the actual end opposite the end 120b is not shown.) In contacting a terminal of an electronic component, the interconnection element 120 would be subjected to a contact force (pressure), as indicated by the arrow labelled "*F*".

In **Figure 1C**, an electrical interconnection element 130 similarly includes a soft core 132 (compare 112) and a hard shell 134 (compare 114). In this example, the core 132 is shaped to have one bend, and may be considered to be U-shaped. As in the example of **Figure 1A**, in this manner, a resilient interconnection between electronic components (not shown) can be effected between the two ends 130a and 130b of the interconnection element 130. (In **Figure 1C**, the reference numeral 130a indicates an end portion of the interconnection element 130, and the actual end opposite the end 130b is not shown.) In contacting a terminal of an electronic component, the interconnection element 130 could be subjected to a contact force (pressure), as indicated by the arrow labelled "*F*". Alternatively, the interconnection element 130 could be employed to make contact at other than its end 130b, as indicated by the arrow labelled "*F'*".

Figure 1D illustrates another embodiment of a resilient interconnection element 140 having a soft core 142 and a hard shell 144. In this example, the interconnection element 140 is essentially a simple cantilever (compare **Figure 1A**), with a curved tip 140b, subject to a contact force "*F*" acting transverse to its longitudinal axis.

Figure 1E illustrates another embodiment of a resilient interconnection element 150 having a soft core 152 and a hard shell 154. In this example, the interconnection element 150 is generally "C-shaped", preferably with a slightly curved tip 150b, and is suitable for making a pressure contact as indicated

by the arrow labelled "*F*".

It should be understood that the soft core can readily be formed into any springable shape - in other words, a shape that will cause a resulting interconnection element to deflect resiliently in response to a force applied at its tip, or at another portion of the interconnection element. For example, the core could be formed into a conventional coil shape. However, a coil shape would not be preferred, due to the overall length of the interconnection element and inductances (and the like) associated therewith and the adverse effect of same on circuitry operating at high frequencies (speeds).

The material of the shell (overcoat), or at least one layer of a multi-layer shell (described hereinbelow) has a significantly higher yield strength than the material of the core. Therefore, the shell overshadows the core in establishing the mechanical characteristics (e.g., resiliency) of the resulting interconnection structure. Ratios of shell:core yield strengths are preferably at least 2:1, including at least 3:1 and at least 5:1, and may be as high as 10:1. It is also evident that the shell, or at least an outer layer of a multi-layer shell should be electrically conductive, notably in cases where the shell covers the end of the core. (The parent case, however, describes embodiments where the end of the core is exposed, in which case the core must be conductive.)

From an academic viewpoint, it is only necessary that the springing (spring shaped) portion of the resulting composite interconnection element be overcoated with the hard material. From this viewpoint, it is generally not essential that both of the two ends of the core be overcoated. As a practical matter, however, it is preferred to overcoat the entire core. Particular reasons for and advantages accruing to overcoating an end of the core which is anchored (attached) to an electronic

component are discussed in greater detail hereinbelow.

Suitable materials for the core (112, 122, 132, 142) include, but are not limited to: gold, aluminum, copper, and their alloys. These materials are typically alloyed with small amounts of other metals to obtain desired physical properties, such as with beryllium, cadmium, silicon, magnesium, and the like. It is also possible to use silver, palladium, platinum; metals or alloys such as metals of the platinum group of elements. Solder constituted from lead, tin, indium, bismuth, cadmium, antimony and their alloys can be used.

Vis-a-vis attaching an end of the core (wire) to a terminal of an electronic component (discussed in greater detail hereinbelow, with respect to **Figures 2A-2C**), generally, a wire of any material (e.g., gold) that is amenable to bonding (using temperature, pressure and/or ultrasonic energy to effect the bonding) would be suitable for practicing the invention. It is within the scope of this invention that any material amenable to overcoating (e.g., plating), including non-metallic material, can be used for the core element.

Suitable materials for the overcoat (shell 114, 124, 134, 144) include (and, as is discussed hereinbelow, for the individual layers of a multi-layer shell), but are not limited to: nickel, and its alloys; copper, cobalt, iron, and their alloys; gold (especially hard gold) and silver, both of which exhibit excellent current-carrying capabilities and good contact resistivity characteristics; elements of the platinum group; noble metals; semi-noble metals and their alloys, particularly elements of the platinum group and their alloys; tungsten and molybdenum. In cases where a solder-like finish is desired, tin, lead, bismuth, indium and their alloys can also be used.

The technique selected for applying these coating materials

over the various core materials set forth hereinabove will, of course, vary from application-to-application. Electroplating and electroless plating are generally preferred techniques. Generally, however, it would be counter-intuitive to plate over a gold core. According to an aspect of the invention, when plating (especially electroless plating) a nickel shell over a gold core, it is desirable to first apply a thin copper initiation layer over the gold wire stem, in order to facilitate plating initiation.

An exemplary interconnection element, such as is illustrated in **Figures 1A-1E** may have a core thickness (diameter, if the core is a wire) diameter of approximately 0.001 inches and a shell thickness of 0.001 inches - the resulting composite interconnection element thus having an overall thickness (e.g., diameter) of approximately 0.003 inches (i.e., core thickness plus two times the shell thickness). Generally, the thickness of the shell will be on the order of 0.2 - 5.0 (one-fifth to five) times the thickness (e.g., diameter) of the core.

Some exemplary parameters for composite interconnection elements are:

(a) A gold core having a thickness (diameter, if the core is a round wire) diameter of 1.5 mils is plated with 0.75 mils of nickel (overall diameter = 1.5 + 2 x 0.75 = 3 mils), and optionally receives a final overcoat of 50 microinches of gold (e.g., to lower and enhance contact resistance).

(b) A gold core having a thickness (diameter, if the core is a round wire) of 1.0 mils is plated with 1.25 mils of nickel (overall diameter = 1.0 + 2 x 1.25 = 3.5 mils), and optionally receives a final overcoat of 50 microinches of gold.

The core need not have a round cross-section, but may rather be a flat elongate element having a rectangular cross-

section.

MULTI-LAYER SHELLS

Figure 2A illustrates an embodiment 200 of an interconnection element 210 mounted to an electronic component 212 which is provided with a terminal 214. In this example, a soft (e.g., gold) core 216 is bonded (attached) at one end 216a to the terminal 214, is configured to extend from the terminal and have a spring shape (compare the shape shown in **Figure 1B**), and is severed to have a free end 216b. Bonding, shaping and severing a core which is a wire in this manner is readily accomplished using wirebonding equipment. The bond at the end 216a of the core covers only a relatively small portion of the exposed surface of the terminal 214.

A shell (overcoat) is disposed over the wire core 216 which, in this example, is shown as being multi-layered, having an inner layer 218 and an outer layer 220, both of which layers may suitably be applied by plating processes. One or more layers of the multi-layer shell is (are) formed of a hard material (such as nickel and its alloys) to impart a desired resiliency to the interconnection element 210. For example, the outer layer 220 may be of a hard material, and the inner layer may be of a material that acts as a buffer or barrier layer (or as an activation layer, or as an adhesion layer) in plating the hard material 220 onto the core material 216. Alternatively, the inner layer 218 may be the hard material, and the outer layer 220 may be a material (such as soft gold) that exhibits superior electrical characteristics, including electrical conductivity and solderability. When a solder or braze type contact is desired, the outer layer of the interconnection element may be lead-tin solder or gold-tin braze material, respectively.

ANCHORING TO A TERMINAL

Figure 2A illustrates, in a general manner, another key feature of the invention - namely, that resilient interconnection element can be securely anchored to a terminal on an electronic component. The attached end 210a of the interconnection element will be subject to significant mechanical stress, as a result of a compressive force (arrow "*F*") applied to the free end 210b of the interconnection element.

As illustrated in **Figure 2A**, the overcoat (218, 220) covers not only the core 216, but also the entire remaining (i.e., other than the bond 216a) exposed surface of the terminal 214 adjacent the core 216 in a continuous (non-interrupted) manner. This securely and reliably anchors the interconnection element 210 to the terminal, the overcoat material providing a substantial (e.g., greater than 50%) contribution to anchoring the resulting interconnection element to the terminal. Generally, it is only required that the overcoat material cover at least a portion of the terminal adjacent the core. It is generally preferred, however, that the overcoat material cover the entire remaining surface of the terminal. Preferably, each layer of the shell is metallic.

As a general proposition, the relatively small area at which the core is attached (e.g., bonded) to the terminal is not well suited to accommodating stresses resulting from contact forces ("F") imposed on the resulting composite interconnection element. By virtue of the shell covering the entire exposed surface of the terminal (other than in the relatively small area comprising the attachment of the core end 216a to the terminal), the overall interconnection structure is firmly anchored to the terminal. The adhesion strength, and ability to react contact forces, of the overcoat will far exceed that of the core end

(216a) itself.

As used herein, the term "electronic component" (e.g., 212) includes, but is not limited to: interconnect and interposer substrates; semiconductor wafers and dies, made of any suitable semiconducting material such as silicon (Si) or gallium-arsenide (GaAs); production interconnect sockets; test sockets; sacrificial members, elements and substrates, as described in the parent case; semiconductor packages, including ceramic and plastic packages, and chip carriers; and connectors.

The interconnection element of the present invention is particularly well suited for use as:

- interconnection elements mounted directly to silicon dies, eliminating the need for having a semiconductor package;
- interconnection elements extending as probes from substrates (described in greater detail hereinbelow) for testing electronic components;
- interconnection elements of interposers (discussed in greater detail hereinbelow); and
- **spring contact elements of connectors (discussed in greater detail hereinbelow).**

The interconnection element of the present invention is unique in that it benefits from the mechanical characteristics (e.g., high yield strength) of a hard material without being limited by the difficulties attendant working with hard materials. As elaborated upon in the PARENT CASE, this is made possible largely by the fact that the shell (overcoat) functions as a "superstructure" over the "falsework" of the core, two terms which are borrowed from the milieu of civil engineering. This is very different from plated interconnection elements of the prior art wherein the plating is used as a protective (e.g., anti-corrosive) coating, and is generally incapable of imparting the desired mechanical characteristic to the interconnection

structure. And this is certainly in marked contrast to any non-metallic, anticorrosive coatings, such as benzotriazole (BTA) applied to electrical interconnect elements.

Both the electrical and mechanical (e.g., plastic and elastic) characteristics of an interconnection element formed according to the invention are readily tailored for particular applications. For example, it may be desirable in a given application that the interconnection elements exhibit both plastic and elastic deformation. (Plastic deformation may be desired to accommodate gross non-planarities in components being interconnected by the interconnection elements.) When elastic behavior is desired, it is necessary that the interconnection element generate a threshold minimum amount of contact force to effect a reliable contact. It is also advantageous that a relevant (mating) portion of the interconnection element makes a wiping contact with a terminal of an electronic component, due to the occasional presence of contaminant films on the contacting surfaces.

As used herein, the term "resilient", as applied to contact structures, implies contact structures (interconnection elements) that exhibit primarily elastic behavior in response to an applied load (contact force), and the term "compliant" implies contact structures (interconnection elements) that exhibit both elastic and plastic behavior in response to an applied load (contact force).

As used herein, a "compliant" contact structure is a "resilient" contact structure. The composite interconnection elements of the present invention are a special case of either compliant or resilient contact structures.

Controlled Impedance

Figure 2B shows a composite interconnection element 220 having multiple layers. An innermost portion (inner elongate conductive element) 222 of the interconnection element 220 is either an uncoated core or a core which has been overcoated, as described hereinabove. The tip 222b of the innermost portion 222 is masked with a suitable masking material (not shown). A dielectric layer 224 is applied over the innermost portion 222 such as by an electrophoretic process. An outer layer 226 of a conductive material is applied over the dielectric layer 224.

In use, electrically grounding the outer layer 226 will result in the interconnection element 220 having controlled impedance. An exemplary material for the dielectric layer 224 is a polymeric material, applied in any suitable manner and to any suitable thickness (e.g., 0.1 - 3.0 mils).

The outer layer 226 may be multi-layer. For example, in instances wherein the innermost portion 222 is an uncoated core, at least one layer of the outer layer 226 is a spring material, when it is desired that the overall interconnection element exhibit resilience.

Using Elongate Ribbons as the Core

As mentioned hereinabove, the core element may be in the form of a flat ribbon, rather than in the form of a wire. For example, as disclosed in commonly-owned, copending U.S. Patent Application No. **08/526,246**, a flat, thin (such as 0.001-0.005 inches) sheet of soft metal (e.g., gold, soft copper alloy, soft aluminum alloy) may be patterned (such as by punching or etching) to define a plurality of core elements. Masking material, such as photoresist, may be applied to selected portions of the core elements to prevent plating of those portions, and selected portions of the core elements are readily shaped (such as bent out-of-plane with respect to the sheet). The core elements (i.e., the unmasked portions thereof) are then overcoated with a hard material such as nickel and its alloys. Finally, the masking material is removed, and the soft metal or the core element that has not been masked may be removed, such as by selective chemical etching. Optionally, in a post-finishing step, the interconnection elements can be overcoated (e.g., plated) with a material exhibiting good contact resistivity characteristics, such as gold.

An advantage of this and, as will be evident, subsequently-described techniques, is that a soft, non-resilient metal sheet, which is easily formed (punched and shaped) can be overcoated to exhibit robust resilient characteristics, in a manner similar to a soft wire core being shaped and overcoated to exhibit resiliency. An additional benefit of this technique is that a plurality of interconnection elements can be formed as individual contact structures, subsequently to be supported in proximity to one another, such as with a support sheet or within a socket body.

FABRICATING SOCKET ELEMENTS

Figure 3 illustrates an embodiment of a technique 300 for making resilient contact structures (spring elements) from a sheet of soft material which has been overcoated with a hard material, according to the present invention. A connector 300 is illustrated which comprises a plastic connector body 302 and a plurality (two of many shown) of interconnection elements 304, 306 embedded within the connector body 302. Each interconnection element (302, 304) is fabricated in a manner similar to that described hereinabove - namely, a soft metal sheet is pattered and formed to have a particular shape, and is then overcoated with a hard metal material 312 to provide desired mechanical characteristics (e.g., resiliency). As in the previous example, a final layer (not shown) of material having excellent electrical characteristics (e.g., gold) can be applied to the overcoated interconnection elements.

The connector 300 is suitable for receiving another mating connector or electronic component, such as is shown by the electronic component 320 having pins 324 and 326 extending from a surface thereof, the pins 324 and 326 inserting into the interconnection elements 304 and 306, respectively.

As mentioned hereinabove, the present invention differs dramatically from the prior art in that an overcoat is used to impart desired mechanical characteristics (e.g., elasticity) to an otherwise non-elastic, readily-formed, inchoate interconnection element (contact structure). In the prior art, coatings (including gold platings) are principally used to enhance electrical characteristics of interconnection elements, and to prevent corrosion thereof.

ALTERNATE EMBODIMENT

Figures 4A-4D illustrate an alternate technique for making a socket elements from a flat sheet of metal.

As shown in **Figure 4A**, a flat sheet of soft metal (e.g., copper) sheet 502 (e.g., foil) is patterned (punched, etched, or the like) to have two, diametrically opposed elongate elements 404 and 406, which are generally in line with one another. The elongate elements 404 and 406 are held at their base ends by a ring 408.

As shown in **Figure 4B**, a one of the elongate elements 404 is bent in one direction, and another of the elongate elements 406 is bent in the same direction so that their distal end portions are generally parallel to one another and orthogonal to the plane the sheet 402.

A plurality of portions of an elongate ribbon of metal can be patterned to have elongate elements which are bent in the manner described hereinabove with respect to one pair of elongate elements 404 and 406.

As shown in **Figure 4C**, a suitable masking material 410 such as photoresist is applied to the sheet 402, outside the area of the ring 408 and the elongate elements 404 and 406.

The sheet 402 is then overcoated (e.g., plated) with a hard metallic material (e.g., nickel or its alloys) 412 (see **Figure 4D**), thereby transforming the shaped elongate elements (404 and 406) into a pair of opposed composite interconnection elements functioning as springs elements. Next, the masking material 410 is removed, and the non-overcoated (by 412) soft metal (402) may then be removed, such as by selective etching, resulting in a plurality of singulated spring element pairs, each pair of

spring elements representing a socket element adapted in use for receiving a terminal 420 (such as a pin) of an electronic component (such as a semiconductor package), as illustrated in **Figure 4D**.

LINKED SPRING ELEMENTS

The aforementioned spring elements (e.g., the single elements 304 and 306 and the pairs of elements 404/406) are best suited to mounting individually to a connector body for receiving terminals (e.g., pins) of an electronic component.

Figure 5A illustrates a plurality of linked interconnect elements, according to the prior art. In this example, an elongate element 500 is formed to exhibit a plurality of individual elongate interconnect elements 502, 504, 506 and 508 which are linked, end-to-end, to one another. Typically, these interconnect elements are formed of a relatively hard material, such as would be suitable for these elements functioning as semiconductor package pins. In use, the linked interconnect elements can be fed through an end effector of automated machinery which will insert the interconnect elements sequentially into, or braze the interconnect elements onto, prescribed positions in or on a support body (such as a semiconductor package body). After each interconnect element is attached to the support body, it can be severed from the remaining linked interconnect elements simply by bending and breaking off at the necked (nicked) portions 503, 505 and 507 of the elongate element 500 forming the interconnect elements. It is within the scope of the prior art that the interconnect elements can first (prior to severing from the elongate element) be shaped.

Figure 5B illustrates a technique 520 for forming a plurality of linked spring elements, according to the present invention. An elongate element 522 of a relatively soft material (e.g., gold or soft copper) is shaped to exhibit a plurality of individual spring shapes. Ultimately, this repeating pattern of spring shapes will evolve into a series of spring elements, linked end-to-end.

In a next step of the technique 520, an overcoat 524 of a relatively hard material (e.g., nickel) is applied to the shaped elongate element. Optionally, prior to overcoating the elongate element, masking material 526 such as photoresist is applied to the elongate element between the ends of adjacent spring shapes, as shown. In this manner, a plurality of composite (soft core,hard overcoat) spring elements may be fabricated in a continuous manner, suitable for attachment to or insertion in a support body (not shown) such as a semiconductor package by automated machinery.

The masking material 526 prevents areas of the elongate element 522 between adjacent composite interconnection (spring) elements from being overcoated. The linked spring elements may then be separated from one another by selective wet etching to result in a plurality of singulated spring elements. Alternatively, the linked spring elements may be fed through automated insertion machinery and as each spring element is inserted into a socket body, the non-overcoated portion of the elongate element may be severed by any suitable means, ,such as by electronic flame off (EFO).

Alternatively, a masking material (526) is not employed, resulting in the entire core 522 being overcoated. The junctions between adjacent spring elements can be nicked (compare **Figure 5A**) by any suitable mechanical means, so that as each spring element is inserted into a socket body, the remaining (supply) of linked spring elements can be broken away from the inserted spring element by automated insertion machinery.

Generally, the materials of choice for the spring elements are identical to those described hereinabove. In a manner similar to that shown in **Figure 2A**, multilayer overcoats can

readily be applied over the core of the resulting spring element.

For the spring shapes illustrated in **Figure 5B**, pressure contact would preferably be made at a mid-portion (compare **Figure 1C**) of the spring element, as indicated by the arrow labelled "F".

An alternate technique 540 for forming a plurality of spring elements, according to the present invention. An elongate element 542 of a relatively soft material (e.g., gold) is shaped to exhibit a plurality of individual spring shapes. In a next step of the technique 520, a masking material 546 such as photoresist is applied to the elongate core element 542 between the ends of adjacent spring shapes, as shown. Next, an overcoat 524 of a relatively hard material (e.g., nickel) is applied to the shaped elongate element. In this manner, a plurality of composite (soft core,hard overcoat) spring elements may be fabricated in a continuous manner. Optionally, the composite spring elements may be separate by one another by removing the masking material and selectively etching to dissolve away the un-overcoated ends of the adjacent spring shapes, resulting in a plurality of singulated spring elements.

Generally, the materials of choice for the spring elements are identical to those described hereinabove. In a manner similar to that shown in **Figure 2A**, multilayer overcoats can readily be applied over the core of the resulting spring element.

For the spring shapes illustrated in **Figure 5C**, pressure contact would preferably be made at a mid-portion (compare **Figure 1C**) of the spring element, as indicated by the arrow labelled "F".

Any number of spring elements having assorted spring shapes can be fabricated in the aforementioned manners - namely, by shaping a relatively soft elongate element then overcoating at least portions of the elongate element with one or more layers of a relatively hard material.

It is within the scope of this invention that the "core" of linked spring shapes can be formed by alternate techniques, such as by etching a thin sheet of metal (such as copper), then plating.

USING AN EXTERNAL SHAPING TOOL TO SHAPE THE ELONGATE ELEMENT

Shaping of elongate elements is readily accomplished using a mechanical shaping tool. This is particular useful for shaping elongate elements that are of a relatively hard material, such as would be employed for monolithic interconnection elements (spring contacts).

Figure 6 illustrates an embodiment 600 using a two-part shaping tool to impart a spring shape to an elongate element. This embodiment is particularly useful for shaping elongate elements made of materials (e.g., spring materials) having a relatively high yield strength, such as elongate elements that are capable of functioning as monolithic spring elements. Generally, it is desired to impart a spring shape to an elongate element 602 which may be (but need not be) bonded at one end to a substrate 608 and which is fed from a capillary tube 604 (or the like).

A one part 622 of the two-part shaping tool 620 is an anvil, and another part 624 of the two-part shaping tool 620 is a die (in the mechanical sense). The anvil 622 and die 624 are positioned on opposite sides of the elongate element, and are operatively linked to suitable mechanisms (not shown) for bringing the two parts together (towards one another), as illustrated by the arrows in the figure.

The inner faces 622a and 624a of the anvil 622 and die 624, are provided with matching mating convex and concave features 626 and 628, respectively. In use, when the anvil and die are brought together, the elongate element 602 acquires the shape of these features.

The elongate element can be severed by a spark while one or both of the anvil and die are in contact with the elongate

element.

Figure 6A illustrates an embodiment 650 of a two-part, "compound" shaping tool comprising an anvil 672 and a die 674 comparable to the previously described anvil and die 622 and 624, respectively.

In this embodiment 650, it is intended to shape and at least notch (nick) an end portion of an elongate element 652 (compare 602) which is not mounted (at one end thereof) to a substrate and which may be supplied by any suitable means (i.e., other than a capillary of a wirebonder). Completely severing the elongate element with the die/anvil is also a possibility. Controlling an electrostatic discharge from an EFO electrode to occur at the nick is also a possibility.

It is within the scope of the invention that a feature is incorporated into the capillary to perform a portion or all of the nicking function. With a wedge bonding tool, this would also be possible. Penetrating a hole (transverse to the bore) in the capillary with a notching tool is also a possibility.

As in the previous embodiment (600), the anvil 672 is provided with a convex feature 676 (compare 626) and the die is provided with a concave feature 678 (compare 628) on their opposing faces so that a desired shape can be imparted to the portion of the elongate element disposed between the die and anvil.

In addition to the above, at least one of the anvil 672 and die 674 is provided with a projecting wedge-shaped feature which is sized and shaped to at least notch (including completely severing) the elongate element. Preferably, both the anvil 672 and die 674 are provided with such features 682 and 684, respectively, as shown in the figure. In this manner, when the

anvil and the die are moved towards one another, with the elongate element disposed therebetween, the elongate element is both shaped and notched (optionally, completely severed). If completely severed, a plurality of shaped elongate elements can be formed in this manner. If only notched, a series of shaped elongate elements, connected end-to-end, can be formed in this manner.

Figure 6B illustrates a series of elongate elements 652a, 652b and 652c, connected end-to-end, separable (e.g., by flexing a one element with respect to the remaining elements) from one another by notches 686a (between elements 652a and 652b) and 686b (between elements 652b and 652c). The elongate elements 652a, 652b and 652c may be shaped, with the shaping tool of **Figure 6** (or of **Figure 6A**). They are illustrated without such shape.

In order to merely notch the elongate element (i.e., as opposed to completely severing the elongate element), the aggregate height (across the page) should be less than the thickness (or diameter, in the case of a wire) of the elongate element.

Figure 7 shows a technique 700 similar to the aforementioned technique of forming a series of shaped elongate elements (652a, 652b, 652c) which are connected end-to-end, wherein as each elongate element is formed, it is inserted into an area of a relatively soft substrate. In this example, the same anvil 672 and die 674 can be employed as in the previous embodiment 600.

Figure 7 illustrates an elongate element 702 (compare 652) being fed (downward, as viewed in the figure) through (between) the anvil 672 and die 674. A first shaped elongate element 702a is shown as having already been shaped and nicked by the anvil

672 and die 674. A next-in-the-series elongate element 702b is shown as being clamped between the anvil 672 and die 674. The end (bottom, as viewed in the figure) of the first shaped element 702a may then be inserted, such as by piercing, at a selected position, into or through a selected area on a relatively (relative to the elongate element) soft substrate 708 (including a relatively hard substrate which is provided with relatively soft areas). Then, by imparting relative motion between the substrate 708 and the clamped next elongate element 702b, the first elongate element 702a can be separated (singulated) from the elongate element 702. This process of shaping, piercing, moving (singulating) can be repeated at numerous locations on the substrate 708, in order to provide a plurality of shaped elements (702a, 702b, etc.) at a like plurality of locations on the relatively soft substrate 708, in any desired pattern, such as in an array. In this manner, a plurality of shaped contact elements can be formed and maintained in a defined spatial relationship with one another, for future use (e.g., as an interposer) or processing (e.g., for overcoating the shaped elements).

For example, the elongate element 702 may be a hard copper or invar wire, the substrate may be a ceramic material with a plurality of lithographically defined areas of gold/tin (80/20), the tips of the shaped elements can be fluxed prior to inserting into the gold/tin areas of the substrate and reflow soldered after inserting into the gold tin areas of the substrate, and the like, and the entire array can be plated (overcoated) with gold or the like. A rigid backing plate 710 is suitably provided behind the soft substrate 708.

Although the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character - it being understood that only preferred embodiments have been shown and described, and that all changes and modifications that come within the spirit of the invention are desired to be protected. Undoubtedly, many other "variations" on the "themes" set forth hereinabove will occur to one having ordinary skill in the art to which the present invention most nearly pertains, and such variations are intended to be within the scope of the invention, as disclosed herein. Several of these variations are set forth in the PARENT CASE.

For example, the sequential ends of an elongate element which has been shaped to exhibit a series (sequence) of linked end-to-end shaped spring contact elements, as described hereinabove, can be inserted into plated through holes in a printed circuit board (PCB). In other words, an elongate element may be shaped and nicked, its end inserted into plated through hole (e.g., with an interference fit), and the mounted part released (broken off) at the nick. A plurality of shaped elements can be mounted to a substrate in this manner, and optionally overcoated to (a) enhance their spring qualities and/or (b) to more securely anchor the spring elements into the substrates.

CLAIMS

What is claimed is:

1. Method of making spring contact elements, characterized by:

feeding an elongate element through a capillary of a wirebonder;

using a shaping tool to impart a spring shape to successive portions of the elongate element as they exit the capillary.

2. Method, according to claim 1, characterized by:

nicking the elongate element between successive shaped portions of the elongate element.

3. Method, according to claim 1, characterized by:

applying an overcoat to the successive shaped portions of the elongate element.

4. Method, according to claim 1, characterized in that:

the elongate element is formed of a material having a relatively low yield strength; and

the overcoat is formed of a material having a relatively high yield strength.

5. Method, according to claim 1, characterized by:

mounting successive shaped portions of the elongate element to a substrate.

6. Method, according to claim 5, characterized in that:

the elongate element is a wire.

7. Method, according to claim 5, characterized in that:

the substrate is an electronic component.

8. Method, according to claim 1, characterized in that:
the shaping tool comprises an anvil and a die, and the elongate element is disposed between the anvil and the die. element to a substrate.

9. Method, according to claim 8, characterized in that:
the elongate element is a wire.

10. Method, according to claim 1, characterized by:
controlling a spark (electrical discharge) used to sever successive portions of the elongate element with the shaping tool.

11. Method of making a plurality of linked spring elements, for electrical contacts comprising:
shaping an elongate core element to have a sequence of a plurality of springable shapes; and
overcoating the core element with a material of sufficient thickness and of sufficient yield strength to impart a desired amount of resiliency to a resulting plurality of linked spring elements and to dominate the resiliency of the spring elements.

12. Method, according to claim 11, wherein:
the core element is a material selected from the group consisting of gold, copper, aluminum and their alloys.

13. Method, according to claim 11, wherein:
the core element is overcoated with a material selected from the group consisting of nickel and its alloys.

14. Method, according to claim 11, wherein:
the core element has a thickness of 0.0005 - 0.0020

inches.

15. Method, according to claim 11, wherein:
the material overcoating the core element has a thickness of 0.00025 - 0.0030 inches.

16. Method, according to claim 11, wherein:
the core element has a thickness of 0.0005 - 0.0020 inches; and
the material overcoating the core element has a thickness of 0.00025 - 0.0030 inches.

17. Method of making a spring element for use in microelectronic applications, comprising:
providing an elongate core element of a relatively soft material; and
overcoating the core element with a shell of a relatively hard material.

18. Method, according to claim 17, wherein:
the core element is overcoated by a process selected from the group consisting of various processes involving deposition of materials out of aqueous solutions; electrolytic plating; electroless plating; barrel plating; chemical vapor deposition (CVD); physical vapor deposition (PVD); and processes causing the disintegration of liquids, solids or gases.

19. Method, according to claim 17, wherein:
the core element is patterned from a sheet of metal.

20. Method, according to claim 17, wherein:
the core element is a material selected from the group consisting of gold, copper, aluminum, and their alloys.

21. Method, according to claim 17, wherein:

the shell is a material selected from the group consisting of nickel and its alloys.

22. Method, according to claim 17, wherein:
the core element has a first yield strength;
the shell has a second yield strength; and
the second yield strength is at least twice the first yield strength.

23. Method of making an spring element, comprising:
forming at least one elongate element from a first material;
overcoating the elongate element with at least one layer of a second material which has a higher yield strength than the first material.

24. Method, according to claim 23, wherein:
the elongate element is shaped to have a plurality of linked spring elements.

25. An interconnection element for microelectronics, comprising:
a core formed of a soft material; and
a hard material, disposed over the core,
wherein said hard material is selected for its ability to impart resilience to the resulting interconnection element.

26. An interconnection element, according to claim 25, wherein:
the core has a yield strength of less than 40,000 psi; and
the hard material has a yield strength of greater than 80,000 psi.

27. An interconnection element, according to claim 25,

wherein:

the core is an elongate member.

28. An interconnection element, according to claim 25, wherein:

a plurality of cores are formed from a single elongate member.

29. Method of making a spring contact element, comprising:

patterning a sheet of material to have a plurality of elongate elements, each elongate element having a tip and having a base portion opposite the tip;

shaping each elongate element to have a springable shape in a region between the tip and a portion of the elongate element adjacent the base portion; and

overcoating at least each entire elongate element with a material selected for its ability to impart resilience to a plurality of resulting spring contact elements.

30. Method, according to claim 29, further comprising:

separating pairs of the spring contact elements from sheet.

31. Method, according to claim 29, further comprising:

supporting a plurality of spring contact elements in a prescribed spatial relationship with one another.

32. Method of making a socket element, comprising:

forming an interconnection element as two tabs, a first tab and a second tab, in a sheet of a first material;

bending the tabs so that one of the two tabs extends in a first direction from the sheet, and so that an other of the two tabs extends in the first direction from the sheet, and so that the one tab is generally parallel to and spaced apart from

the other tab;

overcoating the tabs with a second material which has a higher yield strength than the first material.

33. Method, according to claim 32, further comprising:

providing a plurality of interconnection elements; and

supporting the plurality of interconnection elements in a spatial relationship to one another with an insulating sheet.

34. Method, according to claim 32, wherein:

prior to bending the tabs, the first tab is longitudinally in line with the second tab.

35. Method of making a socket element, comprising:

shaping a core of a relatively soft material into a generally U-shape; and

after shaping the core, overcoating the core with a relatively hard material.

36. Method of mounting a plurality of spring elements to a substrate, said substrate having a plurality of holes, comprising:

(a) fabricating a sequence (series) of shaped spring elements which are linked end-to-end;

(b) inserting a first one of the shaped spring elements into a first hole in the substrate, said spring element being a mounted spring element which is retained in the hole by an interference fit;

(c) breaking the mounted spring element from the remaining linked spring elements;

(d) inserting a next one of the shaped spring elements into a first hole in the substrate, said spring element being a next mounted spring element which is retained in the hole by

an interference fit, and;

(e) repeating steps (c) and (d).

37. Method, according to claim 36, characterized in that: the substrate is a printed circuit board.

38. Method, according to claim 36, characterized in that: the holes are plated through holes.

39. Method, according to claim 36, characterized by:

(f) after inserting a plurality of mounted spring elements into the holes, plating the plurality of spring elements.

40. Method, according to claim 36, characterized by:

(f) after inserting a plurality of mounted spring elements into the holes, mounting the spring elements to an electronic component.

Figure 1A

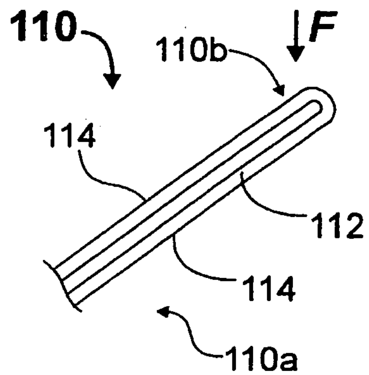


Figure 1B

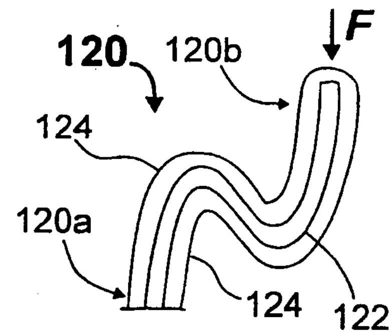


Figure 1C

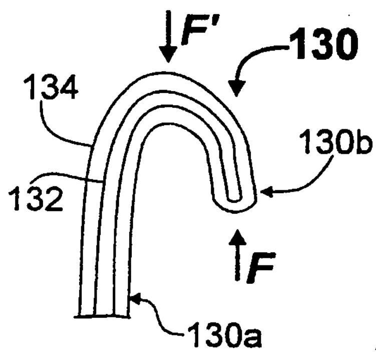


Figure 1D

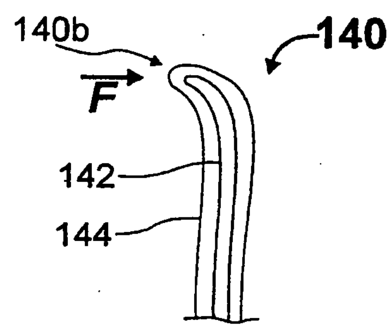


Figure 1E

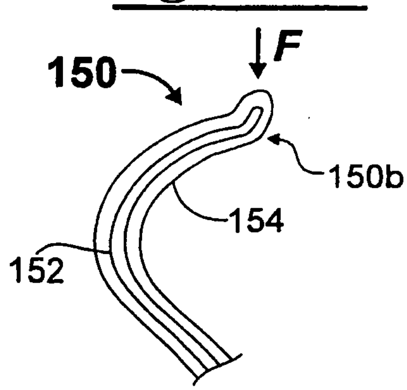


Figure 2A

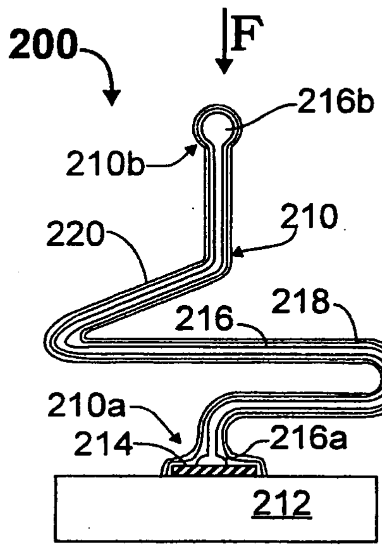


Figure 2B

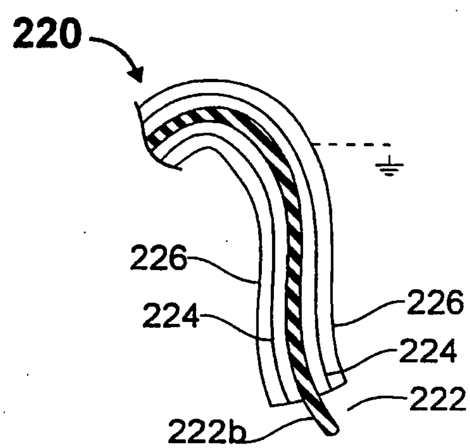


Figure 3

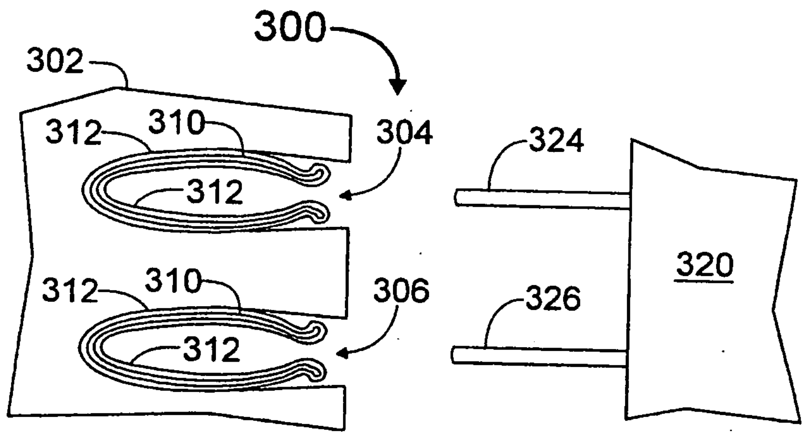


Figure 4A

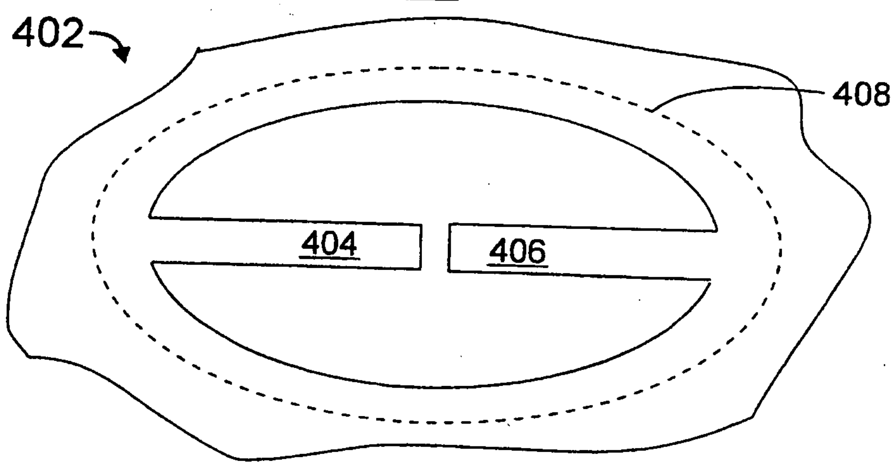


Figure 4B

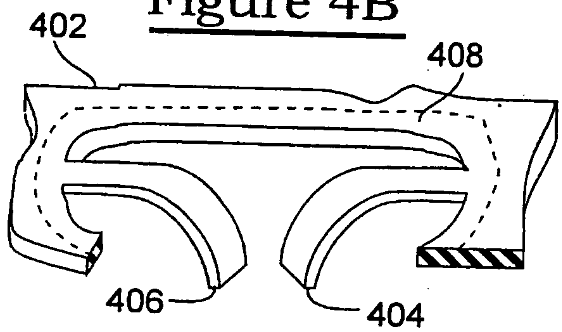


Figure 4C

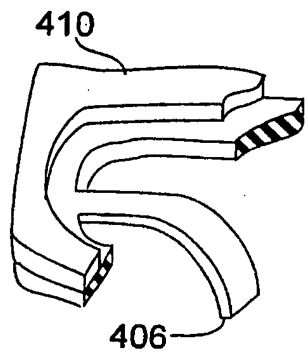


Figure 4D

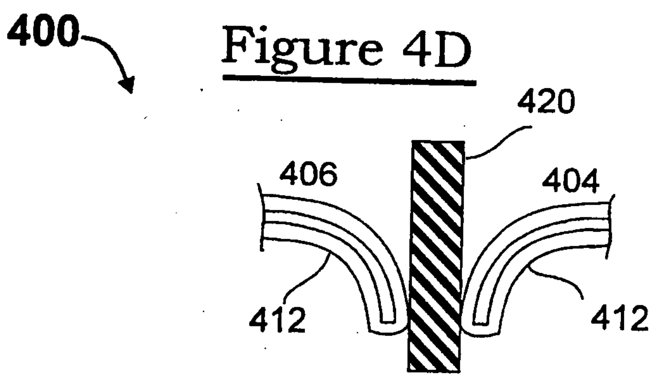


Figure 5A

PRIOR ART

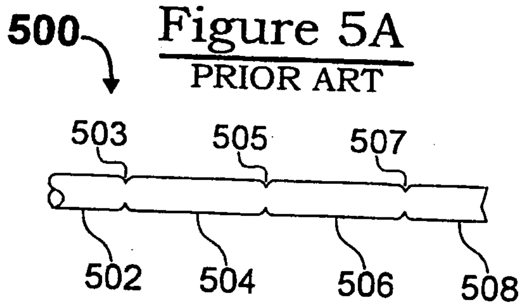


Figure 5B

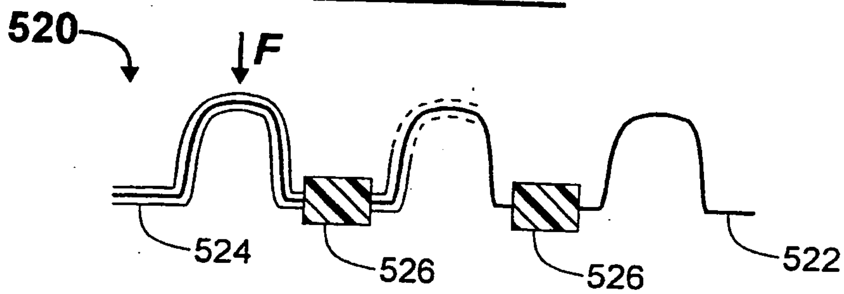
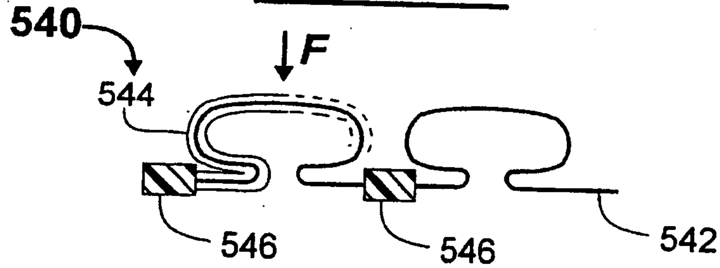


Figure 5C



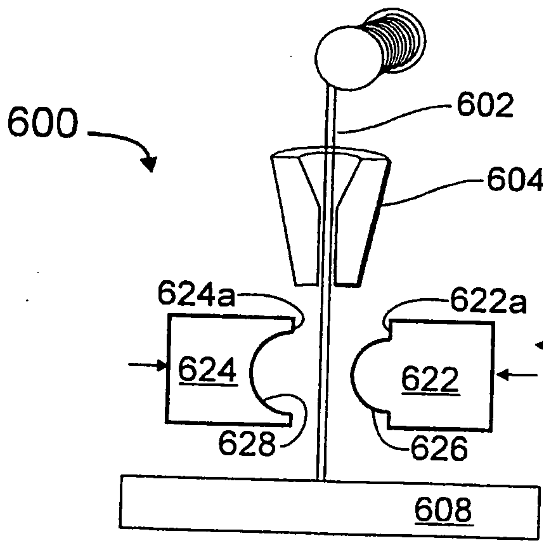


Figure 6

Figure 6A

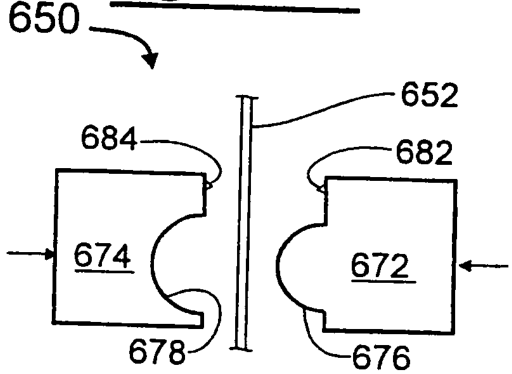


Figure 6B

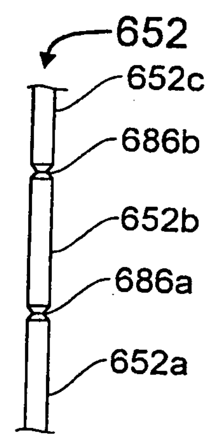
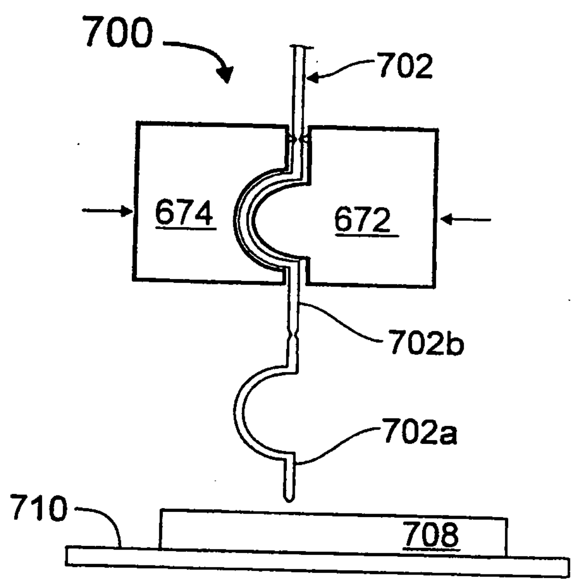


Figure 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/08275

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :Please See Extra Sheet.
US CL : 29/825, 874, 845; 439/886; 428/592
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 29/825, 874, 845, 844; 439/886; 428/592, 605; 427/123, 383.7; 361/773, 776, 789

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 5,163,835 (MORLION ET AL.) 17 NOVEMBER 1992, SEE COL. ,3 FIGS. 2, 9.	25-28, 35 --- 1-24, 29-34
Y	US, A, 5,129,143 (WEI ET AL.) 14 JULY 1992, SEE COL. 2, FIG. 2.	11-16, 25-28
X --- Y	US, A, 5,059,143 (GRABBE) 22 OCTOBER 1991, SEE COL. 7, LINES 5-32.	35 --- 1-34
Y	US, A, 4,025,143 (ROZMUS) 24 MAY 1977, SEE ENTIRE DOCUMENT	1-16
Y	US, A, 4,354,310 (HATTON) 19 OCTOBER 1982, SEE FIGS. 7-9	2, 36

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
22 AUGUST 1996	25 SEP 1996

Name and mailing address of the ISA/US	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/08275

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y --- A	US, A, 5,045,410 (HIESBOCK ET AL.) 03 SEPTEMBER 1991, SEE ENTIRE DOCUMENT	36-40 ---------- 1-35
A	US, A, 4,537,808 (YAMAMOTO ET AL.) 27 AUGUST 1985.	1-40
A	US, A, 3,636,242 (HANSSON) 18 JANUARY 1972.	1-40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/08275

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (6):

H01R 43/02